International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 6233-6240

http://www.ripublication.com

A Novel Optimization of Stresses acting and Failure Rates with Power Transformers

[1]D.Manoharan, [2]Dr.A.Amutha and [3]Dr. S.S.Sivaraju

[1]Chief Engineer and Pursuing the Ph.D. degree in Electrical and Electronics, Karpagam University, Coimbatore, India
[2]Professor and Head of the Electrical and Electronics Engineering Department.
Karpagam University, *Coimbatore, India*
E-mail: manoharanse@gmail.com
[3]Professor and Head of the Electrical and Electronics Engineering Department.
RVS College of Engineering and Technology, Coimbatore, India
sssivaraju@gmail.com

Abstract

This paper proposes a design of High capacity EHV Transformers plays a vital part to supply reliable and quality power for the economic development EHV Transformer belongs being a vital equipment also more costly in the Substation which takes care of Transmission and Distribution of electrical energy improving is reliability is of utmost importance. It is essential to perform monitoring test since each test can give only limited information on the Transformer with that the above case study indicates stringent specification to be made for better servicing over the entire life period and need for the pre-commissioning tests are emphasized in case of case studies I & II.

Index Terms: Control and supervisory equipment, Stresses Acting Transformer, High capacity EHV Transformer, DC Winding Resistance.

Introduction

High capacity EHV Transformers plays a vital part to supply reliable and quality power for the economic development EHV Transformer belongs being a vital equipment also more costly in the Substation which takes care of Transmission and Distribution of electrical energy improving is reliability is of utmost importance. Series of failure of EHV Transformer can have great impact on security and reliability of supply as well as most utilities have a clean mind to assess the condition of their Transformer with the aim to minimize the failures so a to avoid forced outages and to improve the life of the equipment.

Types of Major Failures

Following are the components which have direct bearing on the reliability of the transformer are

- Winding and electrical circuit
- Core and clamping structure
- Bushing and external connections
- ON load / OFF load, Tap changes
- Coolers and Cooling medium
- Control and supervisory equipment

Stages of Failures in Life Time

Failures in the life of equipment attributed to design faults/ in correct assembly. This may be due to inadequate specification and not adhering to stringent quality control and testing at the factory.

a) Due to poor maintenance and non – implementation of condition monitoring technique. Failures during life period can also occur due to external system faults.

b) If materials and components approach their end of life probability of failures increases.

Transformer Design

Magnetic circuit plays a key role in Transformer protection because it influences the excitation current. In steady state the excitation current contains odd harmonics. During energisation or faults the excitation current may become unbalanced and contains large amounts of even harmonics.

The Transformer oil is circulated in some manner, to remove the heat from windings. The oil flows from the bottom of the tank, through the windings and to the top of the tank. This top oil temperature is usually measured and monitored. In addition the winding temperature is monitored to limit insulation deterioration. The higher temperature occurs just inside the insulation on the conductor. The point with the highest temperature is referred to as the hot spot. Another heating source is the eddy current losses in the core.

The resistive is the winding conductors and excitation current losses in the magnetic cores are the two major sources of steady state heating in the Transformer over excitation results in excessive current, eddy current, eddy current losses and core heating.

Fault current quickly increases the winding temperature. Transformer must withstand fault currents for given time. Axial and radial forces are generated on the windings due to these currents which may damage the insulation. The first current peak of fault current causes the maximum force, which determines the withstand limit.

Failure Rats of Power Transformer

Failure rats of EHV Transformer range from 1% to 4% per year for 132 KV to 400 KV class and reports to be arrived 6% for 765 KV systems. The number of through faults may influence the failure rate. Table 1 given below can be taken as typical of Transformer failure modes.

Table 1: Typical failure modes

Sl No.	TYPE OF FAILURE	% OF FAILURE
1	Winding failure	45 to 55
2	Tap change failure	15 to 20
3	Busing failure	5 to 10
4	Terminal board failure	0 to 10
5	Core failure	0 to 5
6	Miscellanies failure	5 to 15

Winding failure still represent the major exposure to Transformer failure with tap changer being the second.

Stresses Acting on Transformer

It is revealed that there are more failure of Transformer due to poor maintenance, improper operation severe weather conditions, manufacturing design defects than due to insulation aging. By analyzing the causes of these failure strategy development can be done to extend the life of old Transformer. Also this can be used to improve the specification while ordering new Transformer and factory test requirements, so that l8ife on new Transformers life can be extended.

The major stresses acting on the winding of a Transformer either individually or in combinations of the following.

1) Mechanical stresses between conductors, leads and windings due to over currents or fault currents mainly due to system short circuits. Possible vibration of supporting parts of the winding or core may also cause mechanical stress. Mechanical forces cause deformation of the winding or of the cleats or leads. Even winding collapse can also occur.

The deformation distortion in the windings causes changes in the geometrical distance of the winding which in turn cause changes in the winding inductances and internal capacitance. These can be deducted by SFRA test, which measure the Transfer function of the Transformer.

2) Thermal stresses due to local over heating over load currents and leakage flex when loading above name plate rating or due to malfunction of the cooling system. Local hotspots, loose joints etc., can give rise to high thermal stresses. A severe partial discharge result in arcing is another possibility.
3) Dielectric stresses due to system over voltages, transient impulse conditions or

internal resonance within a winding. These stresses cause deterioration of physical and chemical properties of the transformer insulations.

To check that manufacturers ensure short circuit withstand capability utilities now introduced SC withstand test on all the transformers. Many transformers could be saved from catastrophic failure by detecting incipient faults in time by condition monitor ring assessment technique. It was also possible to assess the accelerated ageing of cellulosic paper insulation by timely detecting the transformers and resorting to drying out of at .It is the collaborative effort and proactive approach which will helpin achieving designed service life of the transformer. The fault in underlying system will result in abnormal stresses on transformers and their subsequent failures. The faults in zone-2, zone-3 cleared by the operation of backup over protection will invite stresses on transformers and will fail. To avoid failures the following preventive measures are takenRadial mode operation of transformer has been stopped and new guidelines like re-charging of transmission lines after a line fault. 230 KV / 400 KV lines are to be changed from remote end and thereafter to be synchronized in case of fault in line. Numerical are used to clean the fault instantaneously (250 million).Setting of backup protection to avoid short circuit forces for longer duration. Disturbance recorders are being installed in transformer bays for proper analysis of faults / tripping transformers.

Case Studies

The problems uncounted during the initial pre commissioning stage as well as transformer in service given below.(Some of the defects noticed during the pre-commissioning tests are illustrated below)

New Transformer: Case I

Make	:	EMCO Transformer with OLTC
Rating	:	100 MVA
Voltage	:	HV/IV/LV230 kW /110 kW / 11 kV
Year of manufacture	:	2006
Vector group	:	YNaod1

During the pre-commissioning test (31.07.2007) on the newly erected above Auto transformer, the following are noticed.

a) D.C resistances of any two phase H.V windings are not identical

b) The winding resistances in tap 9b and 10 in the “R” phase H.V windings differs abnormally (equal to twice the step value)

DC Winding Resistance

The analysis of Table 2 TESTED ON 31.07.2007

Instrument used	:	SCOPE – TRM 104

HV WINDING :
Winding Temperature : 34°C
Oil Temperature : 34°C

Table 2: DC Winding Resistance Analysis on 31.07.2007

TAP No	1 U – 2 U IN mΩ	1 V – 2 V IN mΩ	1 W – 2 W IN mΩ
1	634.1	632.9	640.3
2	625.3	624.7	631.7
3	617.3	616.2	623.3
4	608.8	607.9	614.8
5	600.4	599.2	606.8
6	591.9	591.0	598.4
7	583.4	582.7	589.7
8	574.9	573.8	581.4
9b	566.0	565.4	572.6
10	582.5	574.1	581.9
11	591.6	582.4	589.9
12	599.1	591.1	598.1
13	608.1	599.0	606.4
14	616.0	607.5	614.5
15	625.3	616.1	622.7
16	634.3	624.5	631.6
17	642.9	633.0	640.0

c) After 9th to 10th Tap the "R" phase resistance values increases twice the step value ie., 17m and the linearity between 1-9 and 9-17 could not be maintained.

The D.C winding resistance test was once again conducted on the newly erected 100 MVA EMCO make Auto Transformer on 14.08.2007 after several operations of OLTC (40 times) as requested by the company and it is observed that the test values are same with the previous test results. However the Transformer is still in service without any increase in DGA gas level. As the Transformer is nearer to the Thermal Power Station Tap changing operation is very minimum.

Case II

Make : Indo Tech Transformer with OLTC
Rating : 100 MVA
Voltage : HV/IV/LV230 kW /110 kW / 11 kV
Year of manufacture : 2008
Vector group : YNaod1

During the Pre-commissioning test (27.04.2009) on the newly erected above Auto transformer, the following are noticed.At Tap No 9b to 10, the “B” phase winding resistance differ abnormally (ie., equal to twice the step value) On detailed open inspection in OLTC by Indo Tech Company at site on 21.10.2009, it was found that there is improper termination in “B” phase Tap changer pre selector switch of terminal No 12.The same was set right and tightness checks in all terminals. After completing the hot oil circulation, the DC resistance test was conducted on 27.10.2009 and found normal and the test results are given below.

DC Winding Resistance
The Analysis of Table 3TESTED ON 27.10.2009
Instrument used : SCOPE – TRM 104
HV + IV WINDING: Winding Temperature : 38°C

Table 3: DC Winding Resistance Analysis on 27.10.2009

TAP No	1 U – 2 U IN mΩ	1 V – 2 V IN mΩ	1 W – 2 W IN mΩ
1	787.3	789.8	789.3
2	774.6	776.5	776.3
3	761.5	763.3	762.7
4	749.2	750.8	750.6
5	736.6	738.3	738.2
6	724.2	725.2	725.4
7	710.7	712.2	712.3
8	698.3	699.8	699.8
9b	685.5	687.1	687.1
10	698.2	699.4	699.6
11	711.4	713.0	713.2
12	723.8	725.3	725.4
13	735.5	738.3	738.3
14	747.9	750.7	750.2
15	760.1	764.1	763.6
16	774.2	776.3	776.3
17	786.8	789.0	788.8

In Service Auto Transformer Case III
Make : EMCO Transformer, with OLTC
Rating : 100 MVA
Voltage : HV/IV/LV230 kW /110 kW / 11 kV
Year of manufacture : 1998(D.O.C 08.01.1999)
Vector group : YNaod1

In one of the 230 kV / 110 kV Substation it was reported that abnormal sound in the transformer was observed by the on duty operator between 7.00 AM to 9.00 AM.The SFRA test conducted on 24.02.2010. The SFRA traces recorded today completely follows with that of the earlier trace taken on 24.08.2008.The Tan delta of the windings were found to be normal.The Tan delta C1 value of all the HV & IV bushings of all the three phases are found to be normal.The Tan delta C2 value of HV bushings in all three phases and that of IV bushings in "Y" & "B" phases are found to be normal.The Tan delta C2 value of IV bushing of "R" phase could not be measured as the voltage could not be applied. There is no short circuit between the Tan – Cap point (whose C2 value with respect to earth is measured) and body. The capacitance between the above points is found to be 0.1/8 nFwhereas capacitance in respect of other two phases ("Y" & "B") are found to be 1.66 nF and 1.71 nF respectively.

Hence it is suspected that the Tan – Cap point of "R" phase IV bushing must lost its insulation causing the abnormal sound. On inspection by the Transformer erection wing it is found that the bushing is defective. After replacing the bushing from the spare and the tests are conducted and the "R" phase IV bushing C2 value is 1.66 nF. The Transformer was put back in to service on 26.02.2010 and no abnormal sound observed. This timely replacement of bushing avoided failure of Transformer and external damages of equipment's.

Case Study IV

Recently, a 250 MVA, 15.75/420 KV, 3-Phase, Generator Transformer failed at site during operation. The physical inspection of the Transformer revealed that the high voltage leads and bushings of the Transformer are damaged and there is deformation of the tank. The damage inside the Transformer looked to be extensive due to brushing of high voltage leads and practically it seemed that the transformer is not repairable at site and there may be a winding displacement in the Transformer. Utility recommended sending back the Transformer to be manufacturer works for repair and replacement of windings. However, the low voltage tests did not reveal any electrical failure of active part of the Transformer as a conclusive test to ascertain the healthiness of the winding and rule out any mechanical movement. The FRA results of the failed Transformer were compared with the factory test results (fingerprints) and the comparison. The low – frequency response up to 2 KHZ is identical indicating neither any short – circuited turns nor any change in the magnetizing characteristics of the transformer. The medium – frequency response up to 50 KHZ also has striking resemblance with factory test results indicating no axial or radial movement of the winding. The low – frequency response did not display any change in capacitance between winding and tank, bushing capacitance or tank grounding. These changes were seemingly expected due to failure of the high voltage leads and the bushings.

Hence, analysis of the FRA data taken at site after failure of the Transformer and its comparison with the FRA data at manufacturer works before dispatch, expressed the confidence on the integrity of the windings or the active part and the failure established was external to the windings. This made it possible to repair the Transformer at site and re-energize. The Transformer is operating satisfactory since more than a year now.

Conclusion

It is essential to perform monitoring test since each test can give only limited information on the Transformer. The above case study indicates stringent specification to be made for better servicing over the entire life period. The need for the pre-commissioning tests are emphasized in case of case studies I & II.

Reference

[1] Workshop on maintenance of Power Transformer by power systems training institute, Bangalore.
[2] IEEMA Journal may 2006 – condition monitoring and life extension Transformer.
[3] Manual on Reliable fault clearance and bushing protection on EHV & UHV Transmission nature part No. 296 of CBIP Sep – 2005.